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Student-Centered Teaching in a Standards-Based World: Finding a Sensible Balance

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Abstract. This paper addresses a tension that exists in the present reform movement in science education. This is the tension between rigor and accountability through standards, benchmarks, and high stakes testing on the one hand and more progressive, student-centered approaches to teaching and learning on the other.

1. Introduction

The current reform movement in science education in the United States has two features that on the surface seem to be in opposition. One is the emphasis on rigor and accountability through high stakes testing, benchmarks, and national and state-developed performance standards. The other is the effort to develop student-centered approaches to teaching and learning, especially as those approaches focus on inquiry methodology or what some would call constructivist pedagogy (Matthews 1994; Driver 1989; Solomon 1989). To some educators these two positions are clearly at odds with each other (Clark & Wasley 1999; Noddings 1999), but others seem comfortable calling themselves student-centered constructivists even as they support standards-based education. Therefore it is appropriate to examine these two thrusts of the current reform movement more closely to see how they can be resolved. This paper will first provide theoretical support for student-centered teaching and learning. Then it will examine the tensions that arise when student-centered learning is implemented in a standards-based environment. Finally, the paper will discuss the standards movement and ways that it can be made more compatible with a student-centered approach to science teaching and learning.

2. Justification for Student-centered Teaching and Learning

Although the recent support for student-centered teaching and learning comes largely from a social constructivist perspective, there have been a wide variety of philosophical and psychological arguments made throughout educational history, both in the United States and in Europe. Justification for a child-centered approach to education ranges from the emancipatory arguments of Friere (1970) and the democratic citizenship arguments of Dewey (1916, 1938) to a body of psychological research that focuses on the positive motivational effects of student autonomy and choice (Deci and Ryan 1987; Lepper and Green 1978). Student-centered teaching and learning is also consistent with the perspective of Piaget (1963) and others who say that students develop personal meaning regarding the physical world through direct experience and dialogue with others about those experiences.

Those who support student-centered teaching do so on the basis of a wide variety of arguments: Some say that students should have the right to choose what is most interesting and relevant themselves because prescribed knowledge is often meaningless to them. Others say that a predetermined curriculum makes students excessively dependent on authority and ultimately produces passive and unengaged citizens. Some argue that when extrinsic motivators are used to interest students in the curriculum, students lose interest after those extrinsic motivators are removed. Others say that the content preferences and interpretations of students have the same legitimacy as those of experts since all knowledge is contingent and culturally derived, and, therefore, no perspective should be privileged over another.

One of the most vocal critics of authority-based teaching is Paulo Friere. According to Friere (1970), the project of all humans is to continuously interpret and reinterpret the world and to transform it through individual and collective actions. Education should not be used to integrate the young into the logic of the present system but to help them change it into something that is more consistent with their existential humanity. Since students already possess a wealth of knowledge from their personal experience with the world and with each other, their insights should be an indispensable part of the educational process. In such a system, says Friere: '... arguments based on "authority" are no longer valid. ... Here no one teaches another, nor is anyone self-taught. People teach each other, mediated by the world ...' (p. 61). The process is one of open dialogue.

Similarly, Dewey (1938) argued that citizens in a democratic society should be inquirers regarding the nature of their physical and social environments and active participants in the construction of society. Citizens should ask questions and have the resources to find answers to those questions, independent of external authority. To prepare them for life in a democracy, formal education needs to give students the skills and dispositions to formulate questions that are personally significant and meaningful to them. Since there is a shared, collaborative aspect to life in a democratic society, students also need to develop a capacity for communal inquiry into the nature of the world.

When we look to psychological justifications for student-centered teaching and learning we find the claim that intrinsic motivation is more powerful in affecting behavior than is extrinsic motivation. Intrinsic motivation involves the good feelings and sense of satisfaction that come from engagement in an activity itself, whereas extrinsic motivation involves getting good grades, receiving the approval of teachers, parents, and peers, or avoiding punishment. There is evidence to suggest that the more we try to motivate students through grades and praise instead of taking advantage of their intrinsic motivation and the pleasure of learning itself, the less interest they show toward their school work and the less effort they put into it (Deci & Ryan 1987; Lepper & Greene 1978). Another key contributor to intrinsic motivation is a task's authenticity. In most schools, however, students are typically placed in artificial environments that are unrelated to the material being taught. According to Ryan and Powelson (1991) this lack of authenticity explains why 'alienation, disengagement, and failures of internalization' are so common in students (p. 50).

Imbedded in this psychological line of reasoning is the claim that one of the most important conditions for learning is a sense of autonomy and self-determination. Deci and Ryan found that when teachers support the autonomous behavior of their students, the students demonstrate: '... greater interest, more creativity, more cognitive flexibility, better conceptual learning, a more positive emotional tone, and more persistent behavior change than behavior undertaken when the functional significance of events is controlling' (p. 1028). Threats, deadlines, evaluation, and surveillance are seen as controlling, and therefore reduce a student's sense of autonomy and self-determination.

In reviewing these various philosophical and psychological positions, we see that there are many reasons for supporting student-centered teaching and learning in science classrooms. It makes use of the natural energy of students to create meaning for themselves and it makes learning more authentic, enjoyable, and intrinsically motivating. The enjoyment and pleasure come from the student's involvement with the learning task, a feeling of control and independence, and a sense of competence in succeeding at tasks that are within the student's range of ability to perform. Student-centered approaches also encourage the development of autonomous individuals who have the skills and dispositions to function effectively in a democratic society.

But perhaps most important to science educators is that many of the attitudes and dispositions we associate with student-centered teaching and learning are also the attitudes and dispositions we associate with scientific inquiry. Curiosity, inquisitiveness, autonomy, independence of mind, freedom from external authority, and a personal search for meaning about the world are the qualities that scientists possess. So it is not surprising that inquiry teaching finds support among advocates of student-centered teaching and learning.

3. Models of Student-centered Teaching and Learning in Science Classrooms

There have been many attempts to implement student-centered approaches in science classrooms over the years. One of the most interesting, but also most difficult to generalize about, is inquiry teaching. Inquiry teaching, in its various forms, has been part of the educational landscape of the United States since the nineteenth century. It has been called inductive teaching, problem solving, project-based teaching, discovery learning, and guided discovery. Most are familiar with the approaches to inquiry teaching that were developed in the United States during the period of National Science Foundation sponsored reform beginning in the late 1950s and similar programs in the United Kingdom that focused on the processes of science, and which introduced practical work into the science curriculum. Inquiry teaching was based on the premise that students could be scientific inquirers in the classroom and generate meaning more or less independently of the teacher. Student inquiries would teach them both the methods of science and the concepts of science. In general, these inquiry-based approaches have historically emphasized the role of the learner in asking questions and investigating problems. Today, the National Research Council (NRC) identifies inquiry as central to science learning, and in a follow-up to the *National Science Education Standards* (NRC 1996) the NRC offers a thorough analysis of inquiry teaching and learning (NRC 2000). Their report explains in detail the variety of meanings of inquiry and ways that inquiry can be utilized in the classroom.

Because of inquiry's historical association and obvious conceptual links with student-centered teaching and learning, as well as the present interest being shown it, this paper will focus on inquiry as the approach to student-centered teaching that has the most relevance for science education today. In the section that follows a number of models of inquiry teaching are presented to demonstrate the tension that is inherent in current reform efforts in science education. This is the tension that exists when inquiry teaching is attempted in a standards-based environment. It is the opposition of the interests and motivations of students on the one hand and the authority of the teacher and the subject matter on the other.

3.1. PROBLEM-BASED SCIENCE TEACHING

Krajcik et al. (1999) in their book *Teaching Children Science: A Project-Based Approach*, describe an approach to teaching science that 'engages young learners in exploring important and meaningful questions through a process of investigation and collaboration' (p. 4). The process begins with the identification of a driving question that is important and meaningful to the students. The driving question can come from the students or from the teacher, but regardless of its source it is related to the real world of the students, is something the students can identify with, and is likely to stimulate sub-questions. Students investigate a question over an extended period of time collaboratively with the other students in the class. Students create products of their work such as models, drawings, or videos that represent their understanding of the issues involved. Then they make public presentations to share this understanding with the other students. Students are expected to learn from each other, from their personal research, and from the teacher.

Much of the motivation to learn under this approach comes from the relevance of the driving question. Although students are given a considerable amount of latitude in the construction of these questions, the authors stipulate that the teacher must make sure that a driving question meets the criterion of worth, that is, it must 'deal with rich science content that students can explore and that helps meet district, state, or national standards ...' (p. 68). This means that student interest and autonomy come into play within the context of a body of knowledge that is defined by established curriculum standards. In addition, the teacher is expected to introduce teacher-directed benchmark lessons to focus student attention on critical aspects of science that help them investigate the driving question. Benchmark lessons are also used to keep student learning consistent with the curriculum objectives of state, local, and national organizations. So although the students are encouraged to generate their own questions, the teacher must always be prepared to intervene in order to keep the content in line with the expectations of curricular experts.

3.2. A PROJECT-ORIENTED APPROACH: SCIENTIFIC CONTENTS IN COOPERATIVE GROUPS LEARNING

At the Second International Symposium on Scientific Literacy in Kiel, Germany in the Fall of 1998, Kai Wollweber, a science teacher at the Integrative Gesamtschüle Eckernforde in Kiel, discussed an experiment in student-centered learning that he conducted at an integrative comprehensive school in Germany where students were studying the chemistry of amino acids and proteins. The method of teaching was the 'project-oriented approach' in which the teacher establishes the general content of the lessons, the arrangement of work groups, and other rules that guide the students' behavior, and then gives the students the freedom to raise questions and to plan investigative activities to find answers to those questions. He wanted to explore whether this method of cooperative learning could be used effectively in a high school chemistry class, that is, whether students would cooperate socially, take responsibility for their learning, listen to each other, share thoughts, and generally engage with the process. He also wanted to know if the students would learn important content about amino acids and proteins. Results showed that students and teacher both had difficulty adjusting to the open-ended approach. Students were uncomfortable with the freedom they were given and tended to rely as much as possible on the textbook and the teacher to guide them. They were also concerned that they were not learning the material that they would be tested on. For the teacher's part, he was eager for the students to be autonomous and generate their own questions and investigations, but often stepped in to help them formulate questions and investigations and find answers to those questions. A natural tension existed between the demands of the curriculum (to learn the chemistry of proteins and amino acids) and the potential interests of the students. The teacher was then left in the awkward position of trying to negotiate those two positions, allowing the students enough freedom to investigate questions that might be of interest to them while still meeting content standards. At the same time, students were not sure how much freedom they really had to pursue their own agendas.

3.3. USING ENGINEERING DESIGN TASKS TO STIMULATE STUDENT INQUIRY

Another approach to student-centered learning involves making use of engineering design tasks to encourage scientific inquiry (Baumgartner 1999). In this approach, students design and build objects to meet specific needs and apply scientific principles to improve those designs. The approach is based on the assumption that real-world practical problems are more authentic to students and thus more motivating. But it is also recognized that students might not know how to draw upon scientific principles to improve their designs, and that they might focus only on the design's performance rather than on the science involved. In addition, students often have trouble: 'framing questions to explore, designing experiments to test their hypotheses, and using data to support their arguments' (Baumgartner 1999, p. 2), as well as delivering successful presentations to their classmates. Recognizing these tensions, Baumgartner concluded: '... the task of providing support for inquiry in these settings falls primarily upon the teacher, who has the responsibility and the opportunity, to frame the activities in which students participate and provide guidance and coaching throughout the design process. ... Teachers must make decisions that involve tradeoffs among goals, such as the tension between covering curricular content and allowing students time to pursue their own investigations' (p. 5).

3.4. BIOLOGY GUIDED INQUIRY LEARNING ENVIRONMENTS (BGuILE)

Still another student-centered science program that encourages student inquiry is the Biology Guided Inquiry Learning Environments (BGuILE) program, a structured, computer learning environment developed at Northwestern University (Sandoval et al. 1999). In this program students are presented with novel problems to investigate, they decide what data to collect and what procedures to follow, and they construct their own explanations for what they observe. In one study where this approach was used (Tabak & Reiser 1999), the specific focus was on encouraging students to provide more scientific verbal explanations for their observations by having them elaborate on their findings, offer explanations for events rather than simply stating them as disconnected facts, establish a line of cause and effect relationships among their observations, and support each of their claims with evidence. Although students made progress in making their discourse more 'scientific', this way of talking about what they had seen in the science classroom did not come easily and the teachers often had to intervene. Once again there was a tension between a prescribed way of doing something and the student's more natural day-to-day way of doing it that raises questions about what exactly it means to utilize a student-centered approach. Should students be free to talk about science in the way they feel most comfortable and allow their discourse to develop naturally out the imperatives of the situation, or should they be moved deliberately by the teacher toward a more normative discursive style?

From the studies and examples cited here, it is evident that in the present environment of curricular and pedagogical reform, a tension exists between the ideals of student-centered learning and the realities of the classroom. Much of that tension is the result of expectations imposed by the teacher, the school, the state, and discipline experts in the form of content standards that represent a body of currently accepted concepts and theories in science. Certainly this is not the only thing that impedes the successful implementation of student-centered learning in school classrooms. It is also true that some students do not find investigating the physical world intrinsically satisfying and do not have the maturity to work either independently or in small groups. Others prefer to have learning outcomes clearly outlined in advance and feel uncomfortable when the expectations are open-ended. But these issues are not the concern of this paper. The central concern here is how standards, benchmarks, and high stakes standardized assessments create an environment that makes student-centered learning more difficult and challenges some of its fundamental principles.

4. The Role of Standards, Benchmarks, and Assessments in Science Eduction Reform

Since *A Nation at Risk* was published in 1983, the United States has been on a mission to raise the performance of its students in comparison to the rest of the world in all school subjects, but especially in science and mathematics. The approach has been to focus on accountability by identifying standards that all students should meet and by creating tests that all students should pass. This approach to educational reform is currently in process in most U.S. states and local school districts. One of the most significant contributions to the reform movement in science education has been the publication in 1996 of the *National Science Education Standards* of the National Research Council. The *National Standards* lays out a vision for science education that state and local officials can use to guide the development of curriculum and instruction in their own schools. The core of the *National Standards* is the content standards. It is toward the achievement of this core body of knowledge that standards for teaching, professional development, assessment, and programmatic issues are aimed. The content standards identify what experts in the field of science education believe to be the essential knowledge that all students should know in order to become scientifically literate, that is, prepared to engage in discussion and debate about science-related issues in society, and to be effective in the workplace so that they can keep pace in a global economy. The confidence that the authors have that this knowledge is essential comes in their admonitions to users of the Standards: 'None of the eight categories of content standards should be eliminated. . . . No standards should be eliminated from a category. . . . Science content can be added. . . . However, addition of content must not prevent the learning of fundamental concepts by all students' (p. 111–112). The *National Standards*, through its content standards, attempts to define what should be taught, learned, and tested.

But whereas the content standards prescribe a body of knowledge to be learned, the teaching and assessment standards are much more student-centered and suggest a more flexible and open approach to choosing content. Teachers are encouraged to be responsive to the needs of students, to adapt instruction to the interests and inquiries of students, and to encourage interdependency through collaborative group work. At the same time, students are expected to accept and share the responsibility for their own learning:

> In successful science classrooms, teachers and students collaborate in the pursuit of ideas, and students quite often initiate new activities related to an inquiry. Students are asked to formulate questions and devise ways to answer them, they collect data and decide how to represent it, they organize data to generate knowledge, and they test the reliability of the knowledge they have generated. (p. 33)

What is not addressed, however, is how such openness to student interest is possible in an environment where the learning outcomes are so clearly defined in advance. As we have already seen, if content mastery is the most important thing, then student-centered approaches can go only as far as the content standards allow. This is made clear in the section of the *Standards* entitled *Developing Self-Directed Learners*.

> Students need the opportunity to evaluate and reflect on their own scientific understanding and ability. Before students can do this, they need to understand the goals for learning science. The ability to self-assess understanding is an essential tool for self-directed learning. Through self-reflection, students clarify ideas of what they are *supposed* to learn. (NRC 1996, p. 88) [italics added]

Under this interpretation of self-directed learning there is little room for teachers or students to wander from the prescribed content unless they cover the prescribed content efficiently enough to leave time for activities of their own choosing. Student-directed learning becomes student learning directed at what subject matter experts say should be learned. So within the *National Standards* is imbedded the age-old tension between organized subject matter and the interests of the student, what Dewey (1902) addressed in his essay, 'The Child and the Curriculum'. This tension is recognized as well in the NRC (2000) report: *Inquiry and the National Science Education Standards*. The report makes two points as it tries to place inquiry teaching in perspective. The first is that the Standards never intended inquiry to be the only recommended form of science teaching. This is made clear in the following statement:

> Although the *Standards* emphasize inquiry, this should not be interpreted as recommending a single approach to science teaching. Teachers should use

different strategies to develop the knowledge, understandings, and abilities described in the content standards. (NRC 1996, p. 23)

The second point is that inquiry teaching itself can take many different forms that vary in the degree of authority that the teacher exercises and the degree of independence given the student. In their analysis of inquiry teaching, the NRC places five essential features of inquiry teaching on a continuum from high student direction to high teacher direction. At the student-directed end of the continuum, the learner engages in scientifically oriented questions, gives priority to evidence in responding to questions, formulates explanations from evidence, connects evidence to scientific knowledge, and communicates and justifies explanations. At the teacher-directed end of the continuum, the learner engages in questions provided by the teacher, is given data and told how to analyze it, is provided with evidence, and is given steps and procedures for the communication of results (NRC, 2000, p. 29). In the teacher-directed model the teacher maintains control over the learning activities and uses those activities to demonstrate and give practice in the prescribed curriculum. Although students will gain experience in the methods of science in both student-directed and teacher-directed approaches, the student-directed approach resembles genuine scientific inquiry in a way that the teacher directed-approach does not. Clearly it is the student-directed approach to classroom inquiry that is threatened in an environment that emphasizes standards and high stakes testing.

5. The Effect of Content Standards on Student-Centered Learning

To this point the discussion has centered on the *National Science Education Standards* because of their significance in U.S. education today. But for the remainder of the paper I will speak more generally about standards-based education and the way standards can help or hinder the efforts we make educating our youth to understand and appreciate science. The *National Standards* are important because they have the potential to dramatically affect the teaching of science as state and local school authorities align their curricula with them and as states and local districts create tests to measure mastery of the content that is prescribed. But individual states are not bound to follow the *National Standards*, and because of this state standards are often qualitatively different from the national standards. One important difference is that whereas most states have created high-stakes tests to accompany their content standards, no such national test exists. The focus on testing has generally led individual states to create curriculum standards that are more detailed and highly specified than the more general national content standards. The discussion that follows takes into account these high-stakes tests and the more specific content standards that individual states have developed from the national standards.

Content standards are important because they identify the knowledge that the young should acquire to be effective citizens in a democratic society. The logically organized disciplines are the product of the most thorough and rigorous examination of the physical world that humans have yet created and an understanding of the disciplines empowers us in fundamentally important ways. Whether we believe that scientific knowledge is socially constructed and influenced by cultural perspectives, or that it is a progressively more accurate approximation to the truth about nature, at any historic moment there is a socially agreed upon canon of knowledge that is the best we can offer. It is this body of knowledge that textbook writers, teachers, and curriculum makers represent to students. Obviously students cannot be expected to learn this content on their own. They cannot by themselves organize laboratory investigations, library research, or discussions with classmates that lead them to an understanding of standard science. They can learn some science that way, but most needs to be learned through the guidance of a skilled teacher.

The question being asked here is how specific should we be in the identification of learning outcomes for students? How much freedom should teachers have to select content and teaching approaches that are relevant to their local situation? The more general the standards, the more room teachers and students have to pursue content that is interesting to them and pedagogical approaches that are more student centered. But along with more general content goals comes the possibility that students are not learning what some may consider to be essential knowledge, and teachers themselves may be uncomfortable with content goals they feel are too open-ended. Generally stated goals also present new challenges regarding accountability. Whereas it is relatively easy to hold teachers accountable for precisely stated and measurable student outcomes, accountability is more difficult when curricular outcomes are stated in general terms.

Obviously the question of how specifically expectations should be stated has no simple answer and no attempt will be made to answer that question here. But what is clear is that highly specified content standards inevitably come into conflict with more general goals of science education including those that are associated with student-centered inquiry learning. If most of a teacher's time is spent developing student understanding of a set body of knowledge, then other more general goals cannot be adequately addressed. There are many legitimate reasons for studying science. In an historical review of the various meanings of scientific literacy, DeBoer (2000) identified nine goals of science teaching that have appeared in the science education literature over the past one hundred years. Included in that list are the following: Science can be studied (1) as a cultural force in the modern world, (2) as preparation for the world of work, (3) for its direct application to everyday living, (4) in the context of science-related societal issues, (5) as a way of thinking, (6) in relation to discussions of events and phenomena that are reported in the popular media, (7) for an aesthetic appreciation of the natural world, (8) to prepare citizens who are sympathetic to science, and (9) for its technological applications and the relationship between science and technology (p. 591). Each of these goals appears in one form or another in the *National Science Education Standards*. Each requires a broad understanding of science. Together they suggest that science education should include the scientific approach to problems, the logic of science, key scientific theories and how those theories relate to our lives, and knowledge of the scientific enterprise, especially how science is conducted in a democratic society. Nothing in this list suggests one particular body of science knowledge over another.

Certainly care must be taken to identify important concepts for students to learn so that their understanding of science is as rich as possible. All other goals of science teaching depend on a foundation of conceptual knowledge. But care must also be taken to insure that teachers have the flexibility to pursue the wide range of goals that this content knowledge supports. When knowledge is specified too precisely it inevitably becomes *the* focus of instruction and takes on an importance beyond what it deserves. Other valuable goals are then ignored. Teachers must have the latitude to choose science content within more broadly stated categories if they are to adequately address the wide range of goals expected of them.

Stating expectations more broadly and leaving room for teacher discretion would help relieve what is becoming a crisis mentality in education as success is increasingly measured against narrowly defined content standards, something that will only get worse as the pressure to demonstrate accountability intensifies. More broadly stated learning outcomes will give individual teachers the responsibility to decide how much autonomy their students can handle and the freedom to encourage genuine inquiry.

6. Summary

There is considerable evidence that, although well-intentioned, standards-based education has created impediments to student-centered teaching and learning while at the same time it has reduced the autonomy and creativity of classroom teachers. Over-specification of standards and benchmarks also presents an image of science that is contrary to its essential character of openness and uncertainty. Content standards should not be offered as a blueprint for learning but rather as a guide to assist decision makers. If content standards were stated more generally, giving local schools and individual teachers more flexibility to choose specific science content, then teachers could teach to their own strengths and to the interests of their students. In addition, they would be free to experiment creatively with pedagogical approaches that are unlikely within the present standards-based educational environment.

For some time now, science educators have been asserting that 'less is more' when it comes to science content (AAAS 1989). But, as Bencze and DiGiuseppe say, for this to happen:

> Governments, corporations, the press, parents, etc. ... need to be convinced that a quality education requires that individual students have significant opportunities to apply a few *essential* concepts, skills, etc. in solution of problems having meaning for them. Through *application* comes *understanding* (Dewey 1938) and, in the context of school science, that would imply more

> opportunities for students to conduct student-directed, open-ended scientific investigation and invention projects, often dealing with their [own] concerns. (Bencze & DiGiuseppe, 2001, p. 1)

We know that learning through genuine inquiry takes time and therefore teachers need the freedom and the time to become 'counselors of opinions' rather than 'suppliers of knowledge' (Buck 1996, p. 9). It is important that in an effort to hold students, teachers, and school officials accountable for higher standards, educational leaders not resort to an over-standardizing of the curriculum that produces lists of learning outcomes that are easily measured but that cause us to lose sight of other important educational goals.

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